Design and Development of Wide Band Rectangular Dielectric Resonator Antenna for Wireless Communication Applications

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LIST OF PUBLICATIONS

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3	A Novel Wideband RDRA for WBAN Applications	International Journal of Engineering and Advanced Technology (IJEAT)	April 2021	ISSN: 2249-8958, Volume-10 Issue-4, April 2021
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ABSTRACT

The recent technological advancements have led to the manifold increase of wireless communication enterprises and application industry over last few decades. High speed wireless applications along with higher data rates raises the demand of compact, reliable, extremely efficient and cost-effective devices. In comparison to the conventional wired long distant communication technologies, wireless communication technology is gaining more confidence among users. Wireless information transfer has become feasible by employing radio frequency (RF) signals in short as well as long distance communication domains. Any wireless system requires a device that converts the radio frequency signals into electromagnetic waves (EM) propagating through guided as well as unguided media and again convert incident EM waves to RF signals, such a device is known as antenna or radiator. With the advent of miniaturisation of electronic circuitry (VLSI) the communication systems require low profile and compact wideband antennas. Dielectric Resonator Antenna (DRA) technology happens to be a potential candidate to address such demands.

Miniaturised Microwave devices is becoming an attractive field of interest for researchers around the globe. These low-profile structures find increasing applications in the domains like advance defence systems, satellite communication, GPS based communication systems, wireless sensor networks, mobile and cellular communication and healthcare detection and measuring devices. These circuits are implied using various techniques such as microstrip technology and dielectric resonator techniques.

Analysis of parameters like design equations, radiation patterns, and feeding mechanisms have made DRAs popular thereby opening the new horizon in comparison to the traditional microstrip patch antennas suffering with lower gain, constricted bandwidth and surface wave losses. Antennas widely recognised as metallic structure transmitting and receiving EM waves, interfacing space and wireless communication apparatus. It is an integral component of any wireless system.

Dielectric Resonator Antennas possess the negligible conductor loss making it far by choice for millimetre wave application. At lower microwave frequency bands, DRA can be used as a compact, low-profile antenna. DRAs were analysed in many shapes like cylindrical, hemi spherical and rectangular. Dielectric Resonator of high permittivity (≥ 20) earlier was thought to be only used as microwave oscillators, filter and was believed to function as energy storing element rather than a radiator. On account of providing flexibility in DR structure, various hybrid shapes like H, stair cased, multi segment, etc are realised. Due to the absence of

conductor, DRA pose to be a strong candidate to be used as antenna in green electronics and as integrated component in various microwave circuits of green communication devices.

Above mentioned exclusive features of Dielectric Resonator Antenna technology find valuable applications in design of compact and miniaturized microwave circuitry in various microwave frequency bands such as C, X, UWB, etc. In year 2002, the FCC declaration of $3.1 - 10.6$ GHz frequency band for UWB technology restored the field of research and development further in to the domain. Consequent to the Federal Communications Commission regulation, a signal with a minimum of 500 MHz bandwidth or alternatively fractional bandwidth greater than 20% can be considered for UWB system.

Alongside the UWB frequency bands, the telecom industry is also looking for antennas yielding super wide band (SWB) response enveloping short- and long-range transmission usage. The tremendously large bandwidths and high data rate like merits of the SWB technology have become an integral component of modern-day wireless communication and also for military and internal security utilities. The challenging job is to design such super wideband compact antennas at practical levels. The distinct properties of dielectric resonator structures and especially rectangular shapes provide additional flexibility for controlling the parameters like impedance bandwidth, co-polarisation and cross-polarisation levels and other broadband characteristics [59]. Thus, Dielectric Resonator technology presents a potential solution for this requirement.

The Thesis aims to attain a communicable -10-dB return-loss bandwidth of 70%, which completely encompasses the FCC's UWB range. The suggested antenna consists of two segments and a partial ground plane to achieve a realised mean gain of 4-5 dBi. The purpose of the DRA is to limit harmful radiation in the lower hemisphere. It works on Body Area Networks and has a wide range of (BAN) applications.

The Thesis confirms a design and publications on an ultra-wideband rectangular RDRA, in which the effects of perturbation on the bandwidth of a partial ground plane and slot allocation on a Dielectric Resonator Antenna is investigated. In order to achieve Ultra-wideband functioning, the Novel Antenna uses two Low-Q modes with overlapping bandwidths.

The Antenna is a conformal patch RDRA, has numerous uses for emerging generation ultra-wideband Radio Frequency device for Body Area Networks and is designed to answer recent research glitches. Recent wideband Body Area Network specifications are enabled by the planned RDRA's compact size and wideband capabilities.

The antenna transmits biomedical signals in the lower European UWB frequency (3.3 - 4.6 GHz) and is well-integrated with modern medical devices. WBAN entices a wide range of applications in human health supervision, including sports, entertainment, defence and the healthcare industry. HFSS 13, a FEM-based 3D EM Simulation Software, was used to build the tiny RDRA Antenna for biotelemetry. Because of its physical compactness, light weight, temperature stability, cost effectiveness, and ease of production, the RDRA is an excellent support for WBAN technology [1]. Because the radiating edges are devoid of conductors, RDRAs have higher radiation efficiency (η) than microstrip antennas, are wideband and have low losses [2,4]. Body Area Networks (BANs) connect several types of sensor nodes affixed to the human body and wirelessly transmit data to a WBAN infrastructure with Pathological monitoring in the healthcare sector, military services and emergency co-ordination, disaster management, rescue services, sports and trainings. The entertainment industry is just a few of the many useful BAN applications that have resulted from the wireless communication network and a variety of compact sensor devices. With the increasing customer needs for WBAN systems, wideband/UWB communication technology has become more commonly deployed with improved accuracy [5,6,9]. Various researchers have been attracted to the usage of DRAs to obtain wideband/UWB response with positive gain for short distance applications such as WBAN, Wi-Max, WLAN, and cognitive radio throughout the last decade [6-14]. The recent technological advancements have led to the manifold increase of wireless communication enterprises and application industry. High speed wireless applications along with higher data rates raises the demand of compact, reliable, extremely efficient and cost-effective devices. In comparison to the conventional antenna and long distant communication technologies, wireless communication technology has gained more confidence among users. The information transfer has become feasible by employing radio frequency signals in short as well as long distance communication domains. With the advent of miniaturisation of electronic circuitry, the communication systems require low profile and compact wideband antennas.

INTRODUCTION

1. Introduction to Wireless Communications

The recent technological advancements have headed to the diverse increase of wireless communication enterprises and the application industry. High-speed wireless applications along with higher data rates nurture the demand for compact, reliable, extremely efficient and cost-effective Antennas. In comparison to the conventional antenna long distant communication technologies and wireless communication technology is gaining more confidence among users. Wireless information transfer has become feasible by employing radio frequency signals in short as well as long distance communication domains.

Miniaturized Microwave devices are becoming a field of interest for researchers around the globe. These low-profile structures find increasing applications in the domains like advanced defense systems, satellite communication, GPS-based communication systems, wireless sensor networks, mobile and cellular communication and healthcare detection and measuring devices. These circuits are implied using various techniques such as microstrip technology and dielectric resonator techniques.

Analysis of parameters like design equations, radiation patterns, and feeding techniques have made DRAs popular thus opening the new horizon as in comparison to the traditional microstrip patch antennas suffering from lower gain, restricted bandwidth and surface wave losses. Antennas are widely recognized as metallic structures transmitting and receiving EM waves, interfacing slots and wireless communication devices. It is an integral component of any wireless system.

Dielectric Resonator Antennas possess negligible conductor loss building it far by choice for millimetre wave application. In addition to the above partially metalized, along with high permittivity DRA's are meant to be utilized as a small low-profile antenna at lower microwave frequency bands.

Alongside the UWB frequency bands, the telecom industry is also admiring antennas yielding super wideband response enveloping short and long-range transmission. The tremendously large bandwidths and high data rate are like merits of the SWB technology have become an integral component of modern-day wireless communication and also for military and internal security utilities. The challenging job is to design such super wideband compact antennas practically. The distinct properties of dielectric resonator structures and especially rectangular shapes provide additional flexibility for controlling the parameters like impedance,

bandwidth, co-polarisation and cross-polarization levels and other broadband characteristics. Thus, Dielectric Resonator technology presents a potential solution for every wireless application requirement.

1.1 Motivation

Over the past decade, several innovative DRAs have been presented for different microwave applications. High radiation efficiency, wideband, low dissipation loss and several other characteristics of DRAs have won many acclaims from researchers by employing novel excitation techniques and several innovative shaping methods. The absence of the metallic radiating structures enhances the radiation efficiency and assists the microwave circuits to function at multiple frequency bands consistently. The properties like the quality factor play an imperative role in the enhancement of bandwidth. The DRA supports a variety of excitation mechanisms thereby providing better control of impedance matching to the designer. The near-perfect integration of DR with techniques such as microstrip patch, partial ground structure, fractal geometries and meta-materials allows antenna research to reduce overall size while simultaneously increasing the antenna's impedance bandwidth.

Consequent to the above statement, some of the unique characteristics of DRAs, a tremendous amount of motivation is drawn towards the application of DRA and to propel thesis understanding the significance of DR technology in the domain of RF and microwave integrated circuits. Also, the research work is motivated by the emerging demand for compact, highly efficient, ease of fabrication, high data rates, fast networks and cost-effective microwave circuits employed in UWB and super wideband (SWB) devices.

1.2 Description of Topic

Wireless communication technology is one of scientists' and researchers' biggest achievements, drastically altering the world of communication and realising our hopes of wirelessly sharing information over long distances. As a result, in recent years, the market for a wide-band antenna with high gain for various wireless systems has grown significantly. Wireless communication is the most demanding of the expanding developments in wireless correspondence, which is established in the IEEE 802.11 standard. WLAN does have a moderate execution cost when compared to other developments because it is limited to a narrow region such as an office, commercial centre, schools or the airports. IEEE 802.11b (Wi-Fi) is the most well-known of the IEEE 802.11a/b/g/n/and so on standards, with a speed of up to 11 Mbps at a range of 2.5 GHz. The IEEE 802.11a is a super speed variant of the

802.11X family that can transmit data at up to 54 Mbps in the 5 GHz frequency [1].

The conventional Microstrip Patch Antenna (MPA) is the first type, while the dielectric resonator antenna (DRA)is the second. In comparison to Micro Strip Patch Antenna (MPA), DRA attracted researchers because it delivers high broadband efficiency even at microwave frequencies, it gives wideband and high radiation productivity. DRA also radiates across the entire surface due to the absence of surface waves [2], [5], [7]. Long S.A. was the first to research DRA and its various shapes, including cylindrical, rectangular, circular, hemispherical and gammadion cross. By comparing to other shapes, the RDRA has appealing features; its mode degeneracy can be dodged by properly selecting its proportions. Additive manufacturing, of which 3D printing is the most prevalent form, can be employed to address these drawbacks. As 3D printers have grown more economical and accessible to the general public as their popularity has expanded. 3D printing can be used to produce the complex structure, demonstrating its design versatility.

Gap couple excitation is employed because it provides the advantage of a disconnected feed network beneath the ground plane, which is another key notion in DRA feeding. As a result, the unwanted coupling or insufficient radiation from the feed is eliminated. It also overcome the problems that planar feed line structures have with deviation. A revolutionary technique is devised, constructed, and tested using a 37 percent impedance bandwidth. To improve acquisition, a variety of metamaterials were layered over the RDRA, raising the antenna's maximum gain by 82.7 percent.

Metamaterials are hypothetical structures with electromagnetic properties that aren't immediately obvious. Positive permittivity (r) and permeability (r) values, or one that is negative while the other is positive, higher than or equal to the unit. At the same time, negative permittivity and permeability (or dual negative material) have been recognised.

On the other hand, all double-negative structures were designed with a high EM resonant frequency, resulting in significant ohmic loss and a limited operational bandwidth. The limited bandwidth, huge losses, and bulky design of metamaterials in the primary quadrant of materials entice researchers to use metamaterials in antenna topologies to attain high gain at microwave frequencies.

2. RESEARCH OBJECTIVES

The Research is intended to investigate and develop few novel microwave dielectric resonator antennas for new-age wireless applications through enhanced performance and precision. About the above, novel DRA geometries have been investigated and the EM behaviour of the presented designs are substantiated both theoretically (using EM Software HFSS and CST Microwave Studio) and experimentally.

2.1 Problem Statement of Thesis

Wireless technology has experienced diverse stages of improvement ever since its initiation. Over a period of time, there have been diverse guidelines of this innovation that advanced out of the requests. On the other hand, low-power, versatile and multi-band wireless devices are greatly preferred for safety and mobility. Some of these demands need the creation of extremely efficient, low-profile and small-size antennas for wireless devices. Two types of new antennas indeed been studied and frequently reported on over last two decades. The two types of antennas are the dielectric resonator antenna(DRA) and the microstrip patch antenna(MSA). Both are excellent candidates for current wireless communications development. Dielectric resonator antennas have recently sparked a lot of attention due to their appealing properties such as: low cost, compact size, low weight, low losses, high radiation efficiency, wide bandwidth and higher gain as compared to more conventional microstrip antennas [28,29]. Dielectric resonators play an important role in a wide range of microwave and millimetre wave communication systems. The characteristic of such DRAs depends on their size, shape and material permittivity. When used at millimetre wave frequencies, the dielectric resonator antenna is particularly efficient due to its low metallic loss. A microwave antenna made of a high-permittivity or partially metalized dielectric resonator on the other hand, can be small and low-profile. Commercially available low-cost, low-loss dielectric materials are now widely available. As a result, more system engineers will be encouraged to use dielectric resonator antennas when producing wireless goods. Hundreds of studies on the design and analysis of dielectric resonator antennas may be found in respected international journals or large international conference proceedings because dielectric resonator antennas are so promising in practical applications. Over the period new design concepts on dielectric resonator antenna have been introduced.

2.2 Objectives of Research

To optimize the DRA's bandwidth and gain, content strategies are employed, including:

- To investigate the design procedures of simple shaped DRAs.
- To investigate various feeding techniques and design of feeding technique that provides additional degrees of freedom to the antenna designer to achieve size reduction, wide bandwidth response and support the excitation for lower order modes.
- Design and develop DRAs for wideband and UWB antennas simultaneously accommodating other parameters such as high gain, omnidirectional broadband radiation patterns, compact size and higher radiation efficiencies.
- To design and verify the Dielectric resonator technology in the sphere of wideband and UWB microwave communication systems.

For the past few decades, DRAs have combined various techniques to attain the above-mentioned objectives. The research work is directed to focus on new DRA designs to integrate with high-performance microwave and wireless applications. Over the earlier years, many researchers have proposed DR-based microwave circuit elements like antenna; filter etc. in millimetre wave applications as the large practical dimension becomes the added advantage.

The thesis is aimed to further realize the Dielectric resonator technology in the sphere of wideband and ultra-wide band antenna design [33-35]. Furthermore, the proposed thesis work focuses on the design of Dielectric Resonator antennas(DRA) for ultra-wideband (UWB) applications in defence, mobile and cellular communications (5G), and biomedical applications.

3. THESIS ORGANISATION

Adjacent to this chapter, the residual segment of the thesis is fragmented into 6 chapters.

Chapter 1 Presentation of DRA to put it normally and the use of DRA in the unique wireless applications are explained. The utilization of RDAR for acquiring upgrades is additionally summed up in this section. The inspiration and issue proclamation are additionally a piece of this section. Notwithstanding the above proposition objective and extent of the highlighted is additionally featured in this chapter.

Chapter 2 Consists of the fundamental concepts of dielectric resonator antennas along with the exhaustive literature survey aligned with the scope of the presented thesis. The survey highlights the evolution of DR technology and enlists the prominent historical advancements. It presents the single-, dual-, multi-UWB band antennas design techniques for various modern

day wireless applications. Also, analytical design solutions to the transcendental equation of rectangular dielectric resonator antennas and other shapes are well depicted.

Chapter 3 Describes the investigations performed on various shapes of the Dielectric resonator antennas. The design and development of wideband antennas based on dielectric resonator technology. It presents simulated designs of different shapes of DR like a hemisphere, cylindrical, rectangular, multi-segment and Ring. A brief introduction to UWB technology is also discussed. The design aspects of various shapes along with the calculation of resonant frequencies and determination of dominant modes are well described. The chapter also highlights the investigation of various antenna parameters like reflection coefficients, VSWR, Radiation patterns, comparison of co-polarization and cross-polarization levels, broadband gain, radiation efficiency and group delay etc. Experiments on a fabricated compact ultra-wideband Rectangular Dielectric Resonator Antenna(UW-RDARA) fed by microstrip line and a conformal metallic patch are also presented [47, 50]. The surface plane of the antenna array shown is modest. The proposed antenna configuration has a 5GHz impedance bandwidth and an operational band of 5.1 - 10.1 GHz, which covers satellite and military X-frequency bands. The antennas are simulated using HFSS 15 and Microwave CST Studio 2016 software. The experimental authentication of selected simulated parameters was also performed.

Chapter 4 Deals with various bandwidth augmentation approaches generated by using various DR forms, such as cylindrical, hemispherical, rectangular and hybrid as well as various feeding techniques. The use of slots and air gaps in the dielectric material to increase the bandwidth of DRA is also discussed. The conclusion includes a comparison of various approaches for increasing DRA's bandwidth.

Chapter 5 Explains the DRA Results and Analysis of Rectangular DRAs for long/short range microwave communications. The thesis projects the DRA applications towards high-speed LTE (5G) mobile and cellular communication, broadband internet services such as Wi-Max and ISM bands. The advent of Microwave imaging technology showing that it is well significant use of DRA in WBAN network and healthcare issues using ultra-wideband technology. In this chapter, there are one antenna configuration presented designed for above mentioned applications. The bandwidth of the proposed antenna structure is enhanced using a defective ground structure (DGS) consisting of slots in the ground plane. The achieved bandwidth of the designed antenna is 5.0 GHz from 6.0-11.0 GHz. The anticipated antenna structures are designed for healthcare services. The second antenna emerging need of recent wireless and mobile communications for 5G has provided the need to develop antennas that

can transmit and receive signals at high data rates and also support large bandwidths. The results of the presented antennas are also verified experimentally.

Chapter 6 finally presents the closing remarks along with the future works/scope in context to the thesis work. Finally, the bibliography includes references to the publications in this area.

The subsequent chapter presents the overview of basic concepts of DRA technology and an equally aligned review of the literature.

I. Scope of the Study

The purposed paper proposition work is to shows proficiently, how to use the previously mentioned properties like Feeding techniques, excitation of different modes inside the RDRAs towards plan and improvement of effective radio antennas for most recent wireless specialized gadgets and systems.

II. Significance of the Study

The proposition shows the design and advancement of ensuing microwave radio antennas:

1) Advancement of RDRA took care of with novel Feeding technique utilizing equal leading strips, chamfered at edges, delivering wideband attributes.
2) Design of smaller UWB RDRA hexagonal moulded DGS with parallel slots and vertical directing strips.
3) he RDRA with UWB incline formed leading patch yielding improved bandwidth qualities and gain.
4) The ultra-wide band multi portion RDRA energized utilizing coaxial test feed to get improved radiation qualities and higher addition reaction.

III. Knowledge Gap

According to the above text, numerous developments have been studied on the DRA to improve the transmission bandwidth and gain through test research by various devices Based on the findings of the preceding study, the researcher used multiple states of the dielectric resonator to improve the DRA's bandwidth improvement and gain. Furthermore, only one parameter, either gain or bandwidth augmentation, has been updated in the aforesaid approaches. In a perfectly fair case, a specific condition of the DRA was just used.

4. Review of Literature

S.K. Behera, et al. (2010) [23] The ring dielectric resonator antenna(RDRA) with an air gap between the dielectric resonator and the surface is investigated in this literature to enable broadband applications. Microstrip line feeds are employed in the proposed antenna to make manufacturing easier. CST Microwave Studio Suite TM 2010 was used to replicate DRA. The simulation results reveal that the wide impedance bandwidth (about 86 percent) is reached in the frequency range 3.20-7.39 GHz. The antenna parameters that are assessed by the CST microwave design tool, as well as the final simulated findings, are presented in this study.

WLAN and RFID applications will benefit from this antenna.

J. Desjardins et al. (2012) [24] A broad-bandwidth CPW Murkowski fractal dielectric resonator antenna(DRA) with high-order modes merged via friction geometry self-identification is proposed in this paper. To understand the suggested antenna function, a comparison of the resonant frequency attributes of the individual frequency antenna and the frequency pole antenna is recommended. The article states, the electrical restriction stops automation from building up, but the frequency magnetic limit boosts the resonance frequency.

Debin Hou et al. (2014) [25] A new Z-shaped DRA for ultra-wideband solicitations is addressed in this section. The three modes of the field are covered using Z-shaped dielectric resonators, with the ultra-wideband obtained by using the air gap between the DRA and the ground plane. Air segment introduction can be efficient, constant, and have a high Q-factor. Another smooth balance change from resonance mode is provided by the graduate feed scheme. To enhance the antenna bandwidth, a detailed parametric research was carried out using CST. According to measurements, around 120 percent of the ultra-wideband has the DRA 10dB required reflectivity. For antenna suggestions and ultra-wideband applications, a new Z-shaped dielectric resonator antenna was investigated. To improve antenna design, symmetric studies have been undertaken. The findings show that increasing antenna bandwidth via air space and bevel patch delivery methodologies is extremely successful. The measured data from the suggested DRA was analysed, and a bandwidth of 2.5-10.3 GHz was revealed, that could be a viable option for ultra-wideband communication systems.

Amir Altaf et al. (2015) [26] Circular polarisation is one of the most common types of polarisation. Spidron in a DRA is the subject of this research. The wide 3 dB (AR) axial ratio bandwidth was discovered by using an analog-digital re-entry device to collect a C-shaped slot that generates a circularly polarised column. The antenna should establish contact with the ground plane's C-shaped slot and the 50 microstrip feed line, according to the design. The antenna prototype was built and placed to the test. As a result, the suggested antenna with a feed structure can be used in a wide range of broadband communication systems.

X. S. Fang et al. (2010) [27] A minor difference in dielectric resonator antenna (DRA) is investigated in this study. Two matched conductive strips connected to the lower layer's output produce the resonating DRA. The sum of conformation is utilised to eliminate feed system losses, allowing differential gain to equal single-ended gain. Furthermore, compared to the single-ended form, along with that gain is reduced across the polarisation field. The replicated propagation, radiation characteristics and antenna gain were all repeated for the specified DRA

and the results were quite close to the observations. An alternative hollow DRA with suitable cables has been shown as a compact option.

Abdel R. Sebak et al. (2010) [30] This material includes a study to develop a novel form of circularly polarised antenna for millimetre wave applications. A typical hybrid micro strip/elliptical dielectric ring resonator achieves a rather high antenna gain. Circular polarisation was achieved by the T-shaped connection groove. This research employs a ring DRA to achieve axial ratio a/b: b/b proportional frequency and enhance tuning. The mode bandwidth is 12 percent and the axial proportional bandwidth is appropriate, according to the measurements (10 percent). The measured gain for most operating bandwidths exceeds 9dBi. The millimetre wave frequency of the proposed antenna can easily reach 9dBi or more. As a result, the antenna is ideal for a wireless film wave communication system with a small range.

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